METHOD AND APPARATUS FOR CALIBRATING A TILED DISPLAY

CROSS REFERENCE TO CO-PENDING APPLICATIONS

The present application is related to U.S. patent application Ser. No. 09/159,340, filed Sep. 23, 1998, entitled "METHOD AND APPARATUS FOR PROVIDING A SEAMLESS TILED DISPLAY", and U.S. patent application Ser. No. 09/159,024, filed Sep. 23, 1998, entitled "METHOD AND APPARATUS FOR CALIBRATING A DISPLAY USING AN ARRAY OF CAMERAS", both of which are assigned to the assignee of the present invention and incorporated herein by reference.

"The invention described herein was made in the performance of work under NASA Contract NAS1-20219 and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, as amended (42 USC 2457)."

BACKGROUND OF THE INVENTION

This invention relates to calibrating displays, and more particularly, to calibrating tiled projection displays that use multiple projectors to produce larger and/or higher resolution images.

Multiple projector systems have been proposed and used for many years. In the 1950s, the "CINERAMA" system was developed for the film industry. The CINERAMA system projected three films using three separate projectors, which were combined to form a single panoramic image. Disneyland continues to use a similar multiple projector system. At Disneyland, a circle of projectors shines onto a screen that circles the wall of a round room.

In the video field, multiple projector systems have been proposed and used for a number of specialty applications. For example, U.S. Pat. No. 4,103,435 to Herndon and U.S. Pat. No. 3,833,764 to Taylor suggest using multiple projector systems for flight simulators. In many of these systems, multiple video screens are placed next to each other to form a large image display for multiple projectors. A difficulty with many of the video based multiple projector display systems is making the multiple images appear as one single continuous image on the display screen.

When two images are projected side-by-side on a single screen, there is normally a seam between the images. The final display image will either appear as two images placed side-by-side with a gap in between or, if the images are made to overlap on a single screen, there will be a bright line where the two images overlap. Because of the inconsistencies in conventional cameras, video processing, delivery channels, displays and, specifically, projectors, it is exceedingly difficult to perfectly match the resultant video images so that no tiling artifacts appear among the images. If the images are brought very close together on the same screen, there is typically both gaps and overlaps at each seam.

The article entitled Design Considerations and Applications for Innovative Display Options Using Projector Arrays, by Theo Mayer, SPIE Vol. 2650 (1996), pp. 131–139, discloses projecting a number of discrete images in an overlapping relation and ramping the brightness of the discrete images in the overlapping regions of each image. Mayer discloses using a blending function to fade down each overlapping edge of the discrete images in such a way so as to compensate for the gamma (video signal reduction vs. light output curve) of a phosphor, light valve or LCD

projector, with the goal of producing a uniform brightness across the display.

U.S. Pat. No. 5,136,390 to Inova et al. recognizes that the blending function typically cannot be a simple even ramping function. A typical video projector produces an image that becomes darker toward the edges of the image as a natural function of the lens system used, and has a number of bright and dark portions caused by normal irregularities in the signal, intermediate signal processor, projector, screen, etc. These inconsistencies typically vary from one video component to another, and even among different components with similar construction. Also, different types of projectors often respond differently to the same amount of brightness modification. Thus, a simple ramp of the brightness in the over-lapping regions can produced light and dark bands and/or spots in the resulting image.

To overcome these limitations, Inova et al. suggest applying a simple even blending function to the overlapping regions of the image, as suggested by Mayer, but then manually tuning the simple even blending function at specific locations to remove the visible artifacts from the display. The location of each artifact is identified by manually moving a cursor over each location that is identified as having an artifact. Once the cursor is in place, the system tunes the corresponding location of the blending function so that the corresponding artifacts are removed.

Since each artifact must be manually identified by a user, the process of calibrating an entire display can be time consuming and tedious. This is particularly true since many displays require periodic re-calibration because the performance of their projectors and/or other hardware elements tend to change over time. In view of the foregoing, it would be desirable to have a display that can be calibrated and re-calibrated with less manual intervention than is required by Inova et al. and others.

SUMMARY OF THE INVENTION

The present invention overcomes many of the disadvantages of the prior art by providing a display that can be calibrated and re-calibrated with little or no manual intervention. To accomplish this, the present invention provides one or more cameras to capture an image on the display screen. The resulting captured image is processed to identify any non-desirable characteristics including visible artifacts such as seams, bands, rings, etc. Once the non-desirable characteristics are identified, an appropriate transformation function is determined. The transformation function is used to pre-warp the input video signal such that the non-desirable characteristics are reduced or eliminated from the display. The transformation function preferably compensates for spatial nonuniformity, color non-uniformity, luminance non-uniformity, and/or other visible artifacts.

In one illustrative embodiment, a tiled projection display is provided that has two or more projectors arranged in an array configuration. The projectors may be direct write (e.g. CRT, LCD, DMD, CMOS-LCD) or any other type of projector. In a tiled type display, each of the projectors preferably projects a discrete image separately onto a screen, wherein the discrete images collectively form a composite image. The discrete images may or may not overlap one another. A camera is then directed at the screen to capture a capture image of at least a portion of the composite image. The capture image may encompass less than one tile, about one tile, the entire composite image, or any other portion of the composite image that is deemed desirable.

A determining block then determines if the capture image has one or more non-desirable characteristics. The non-